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Meat Science 58 (2001) 287–292

MEAT SCIENCE

www.elsevier.com/locate/meatsci

Hydrodynamic shockwave tenderization effects using a cylinder processor on early deboned broiler breasts

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Received 8 August 2000; received in revised form 22 December 2000; accepted 22 December 2000

Abstract

In separate experiments, chicken broiler breasts were deboned (45 min postmortem, 52 min, respectively) and either exposed to high pressure hydrodynamic shockwaves (HSW) 25 min after deboning (77 min postmortem) or after 24 h of storage (4°C) respectively, and compared to companion control breasts. HSW were produced in a cylindrical HSW processor with 40-g explosive. Warner-Bratzler shear (WBS) values of the HSW breasts treated at 77 min postmortem were not different than the controls. HSW treatment decreased ($P < 0.05$) the WBS values of the stored and cooked breasts by 42.0% as compared to non-treated controls. Cooking losses were not affected by HSW. In general, raw and cooked color characteristics (CIE $L^*a^*b^*$) were not affected by the HSW. HSW treatment at 25 min after deboning (77 min postmortem) may require a higher pressure front or delayed treatment after postmortem aging to improve tenderness.

Keywords: Chicken; Early deboned; Tenderness; Shockwave; Cylinder

1. Introduction

A major limiting factor in broiler processing is the time needed to age chicken breasts prior to deboning. Early deboned (non-aged) breasts are unacceptably tough to consumers (Lyon, Hamm, & Thompson, 1985). The aging time prior to deboning of 4–7 h postmortem results in a costly conversion process as it involves additional handling, extra storage space, added refrigeration, and results in considerable shrinkage due to purge (Meek et al., 2000). Other process technologies have provided positive results in improving early deboned broiler breast tenderness (Birkhold, Janky, & Sams, 1992; Dickens & Lyon, 1995). However, none of these technologies have demonstrated a consistent and applicable improvement in breast acceptability for the poultry industry.

The Hydrodyne process was invented by Long (1993, 1994) and initially developed to tenderize red meats. This process incorporates hydrodynamic shockwaves (HSW) produced by the detonation of a small amount of explosive in a water-filled container to physically tenderize the myofibrillar structures within the myofibrils. Solomon (1998) found that HSW effectively tenderized beef, pork, and lamb.

HSW has been effective in tenderizing early deboned broiler breasts (Meek et al., 2000) when the shockwave treatment was applied after storage (24 h postmortem). Meek et al. (2000) used the 1060 L hemishell design (including eight suspension supports) for the application of HSW to broiler breasts. This equipment was designed as a large batch type operation and as such would not be a viable approach for processing poultry. Currently, there is no known published material utilizing the HSW technology on tenderizing deboned broiler breasts treated immediately after deboning. The objectives of this study were to determine (1) the ability to tenderize broiler breasts when hydrodynamically shockwave processed soon after deboning (77 min postmortem) and (2) the

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0309-1740/01/$ - see front matter
PII: S0309-1740(01)00028-6

tenderization effects using a cylinder-shaped hydrodynamic shockwave processor.

2. Materials and methods

2.1. Cylinder and packaging system

All explosive testing was conducted in a specially designed 2.54-cm thick stainless steel cylinder (Cylinder Research Prototype 1, Hydrodyne™ Inc., San Juan, Puerto Rico) processor having an outer diameter of 20.3 cm and a height of 48 cm. The breasts were suspended in the center of cylinder between two strip explosive charges taped to metal inserts (2.5 cm wide by 48 cm long) suspended at 180° from each other on the inner wall of the cylinder. The cylinder was placed in the steel hemishell (Model: small-scale research hemishell prototype, Hydrodyne Inc., San Juan, Puerto Rico) for containment during detonation. The 5.1 cm thick steel hemishell had a 31 cm inner diameter and was 76 cm deep. The breasts ($n=2$, each breast from different chickens) were packaged in 0.5 cm thick, 3.8 cm inner diameter, 46 cm long vinyl tubing (#5233K-76, McMaster-Carr, New Brunswick, New Jersey) and sealed using 3.8 cm diameter, 5.1 cm length plastic plugs (# 003003 Plastisol, Rutland Plastic Tech, Pineville, NC). Two plastic cable ties were used on each end of the tube to secure the plugs. The vinyl tubing was then sealed on both ends by heating the ends with a heat gun (model AH-751, Master Appliance Corp., Racine, WI 53401) and then clamping the hot ends together until cooled. The sealed ends of the tubing were filled with water by a hypodermic needle and the needle hole sealed with duct tape. The breasts were packaged in water with special attention given to avoid air bubbles in the package. The cylinder was placed 12 cm above the bottom of a water-filled (approximately 13°C) research hemishell.

2.2. Explosive and handling

A certified explosive expert performed the handling and detonation of all explosive (sheet explosive containing a proprietary blend provided by Hydrodyne Inc.). Two detonation devices were used for each shot with one device on each piece of the sheet explosive.

2.3. Preliminary cylinder testing

Fresh early deboned skinless chicken breasts (*pectoralis major*) were obtained from a Virginia Processor for use in preliminary testing. The treatments included early deboned (deboned 45 min postmortem) chicken breasts that were HSW treated at 24 h postmortem. Each breast was individually labeled with a brine tag. The breasts for treatment were packaged within the vinyl tubing according to aforementioned specifications. Each packaged breast was HSW treated using one of several different explosive levels (60, 30, 20, and 15 g). Two breasts from different chickens were used for each shockwave combination. The objectives for the preliminary testing were: (1) determine if the breasts would remain intact allowing for instrumental analysis; (2) pretest the designed packaging system; and (3) pretest for any unforeseen mechanical flaws in the general design.

2.4. Experiment 1

2.4.1. HSW treatment of breasts at 25 min after early deboning

Live broiler chickens ($n=12$) were transported via truck from a commercial poultry company (Rocco Farm Foods, Inc., Edinburg, Virginia). The birds were held off feed overnight following arrival at the Meats Laboratory of Virginia Polytechnic Institute and State University resulting in a 36 h fast before slaughter. The birds were allowed free access to water. The birds (two per replication) were electrically stunned (Model VS 200, Midwest Processing Systems, Minneapolis, MN) for 8 s (stunner dial setting, 4) and then immediately bled for 15 s. The carcasses were placed in a custom built scalding bath (62°C, 25 s), mechanically defeathered (Model BP21, Brower, Inc., Houghton, IA 52631) and eviscerated by hand. Carcasses were placed in ice slush at 12 min postmortem and chilled for 40 min. Breasts were hand deboned prior to HSW treatment.

Treatments included breasts that were early deboned at 52 min postmortem and then (1) HSW treated 25 min after deboning, or (2) held as non-treated (control) counterparts of the treated breasts. Treated and non-treated breasts alternated between the right and left breasts. Individual boneless, skinless breasts averaged 96.3 g (standard deviation, 7.5 g). Control and treated breasts were packaged in the vinyl tubing as previously specified. The HSW treatment used was 20 g of explosive to each side of the packaged breasts. This experiment (six replications/two birds per replication) provided testing of the shockwave treated breasts treated 25 min after early deboning.

2.5. Experiment 2

2.5.1. HSW treatment of breasts 24 h after early deboning

On the day of harvest, fresh boneless, skinless anatomically paired chicken breasts (*pectoralis major*) were obtained from a poultry processor (Rocco Farm Foods, Inc., Edinburg, Virginia) and transported on ice within vacuum packaged bags to meat science laboratory. Individual breasts averaged 106.2 g (standard deviation, 24.6 g). Breasts were stored on ice overnight before treatment. The treatments included breasts that were

early deboned at 45 min postmortem at the poultry processing plant and then (1) HSW treated at 24 h postmortem, or (2) held as the non-treated companion 24 h postmortem breasts. Treated and non-treated (control) breasts were alternated anatomically between the right and left breast. The shockwave treatment used was 20 g of explosive on either side of the vinyl tube packaged breasts for a total of 40 g of explosive. This experiment (fifteen replications/two birds per replication) provided testing of the HSW treated breasts at 24 h postmortem.

2.6. Instrumental color determinations

Color (CIE $L^*a^*b^*$) of the breasts treated with HSW and the controls were determined using a chroma meter (Model CR-200, Minolta Camera Co., Ltd., Osaka, Japan). The chroma meter was calibrated using a standard white Minolta calibration plate (No. 20933026; CIE $L^* = 97.91$, $a^* = -0.70$, $b^* = +2.44$). Three readings were taken on each raw and cooked breast on the skin and bone side. Raw breasts were exposed to air for 2 min prior to color analysis by suspending the breast by one end. An average was calculated for each breast.

2.7. Cookery method and cooking loss determinations

Control and treated breasts were individually vacuum packaged (15.2×20.3 cm, 3 mil barrier bags, Item # 030026, Docket # 501655, Koch Supplies, Inc., Kansas City, MO) and cooked using a sous vide method (Meek et al., 2000). The breasts were cooked to an internal temperature of 78°C in a circulating water bath custom made at Virginia Polytechnic Institute and State University, preheated, and maintained at 80°C. Several ($n = 3$) representative breasts were placed in different locations in the water bath with type T thermocouples inserted through adhesive patches (0.64 cm width, 2.54 length, Thermwell, Inc., Patterson, NJ) into the samples to monitor core temperature. Temperature data was collected using an automatic data recorder (Model 5100, Datalogger, Electronic Controls Design, Inc., Milwaukie, OR). The breasts were removed from the bath when a 78°C internal temperature was reached and cooled at room temperature for 30 min. After cooling, (WBS) shear values were determined on individual breasts. The cooking loss was calculated on all samples cooked for tenderness determination as based on raw weights.

2.8. Shear force measurements

Tenderness was assessed by an objective texture procedure described by Meek et al. (2000). Two to three adjacent 1.0-cm strips were cut from the frontal area of the cooked breast parallel to the muscle fibers and then trimmed to a thickness of 1 cm. Each strip was sheared once and an average was calculated. Samples were sheared perpendicular to the muscle fibers using a Warner-Bratzler shear attachment mounted on an Instron (Model 1011, Instron Corp., Canton, MA) testing machine using a 50 kg load transducer and a crosshead speed of 200 mm/min. Peak force (kg) data was recorded and an average calculated for each breast.

2.9. Statistical analysis

WBS, cooking loss and color data were statistically analyzed with each having a control and a shockwave treatment (Experiment 1, 6 replications; Experiment 2, 15 replications) using a *t*-test (SAS, 1996).

3. Results and discussion

3.1. WBS force values

The early deboned breasts that were treated 25 min after deboning (Experiment 1) were not different ($P > 0.05$) in WBS values than their companion control breasts (Fig. 1). Muscles with shorter sarcomeres have been reported to produce less tender meat (Birkhold et al., 1992; Sams, Janky, & Woodward, 1990). It is theorized that in order for HSW to tenderize early deboned chicken breast when processed soon after deboning, much greater structural damage must occur to overcome the impact of sarcomere shortening in comparison to tenderizing stored (24 h) breasts.

The HSW treated breasts after 24 h storage of early deboned breasts (Experiment 2) were 42% more tender ($P < 0.05$) than their companion control breasts (Fig. 1) when evaluated after cylinder HSW treatment. In comparison, Meek et al. (2000) used 350 g of a binary explosive at 20 cm from the meat face in a hemishell (1060 L) and reported a 19.1–28.3% improvement in tenderness in early deboned broiler breasts (stored 24 h) after shockwave treatment. In the current study, the larger increase in tenderness improvement was most likely due to increased efficiency in the cylinder design in which the HSW was applied to the breasts. In the hemishell design, a centrally located explosive is detonated in which only 50% of the energy is directed at the product (Long, personal communication). In contrast, the explosive in the cylinder when detonated has a majority of the energy directed toward the centrally suspended product. The shockwave treated breasts had an average WBS force value of 2.5 kg, which would be acceptable to approximately 94% of consumers whereas control breasts had an average shear value of 4.4 kg, which would be acceptable to only 68% of consumers. Consumer acceptability was established in a separate study in this laboratory (Schilling, 2000).

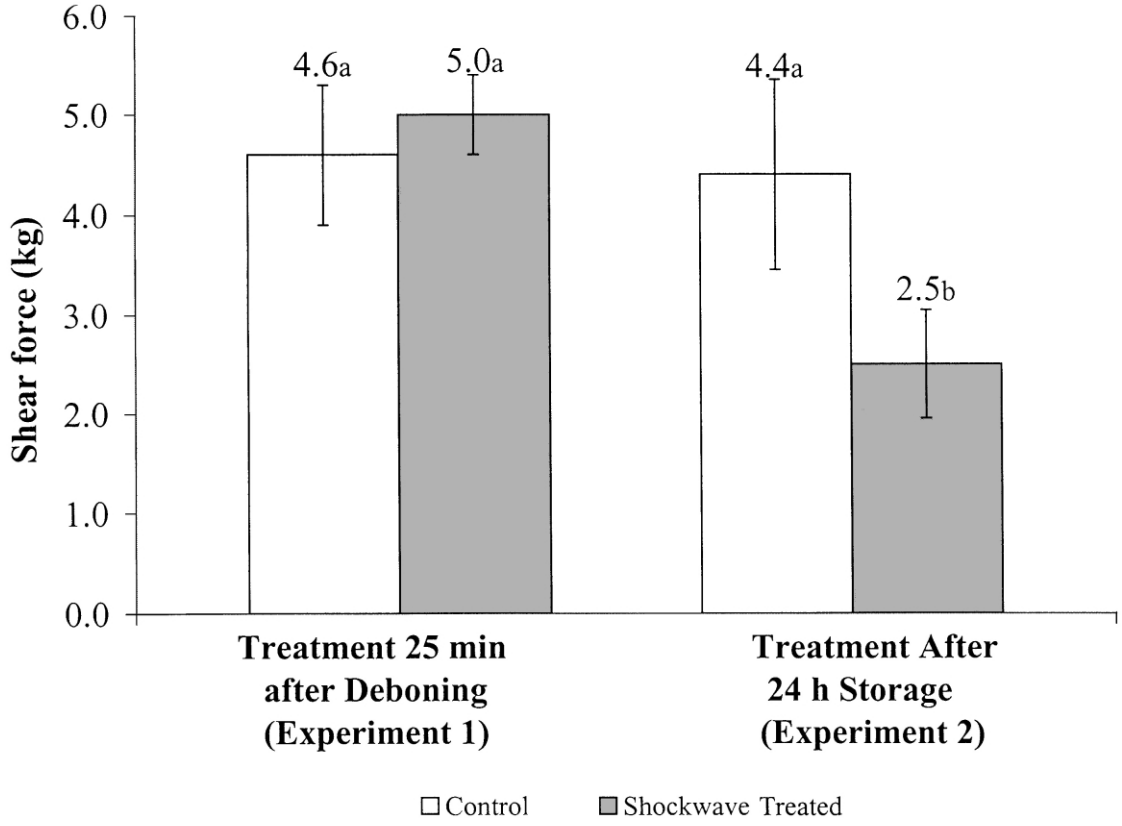

Fig. 1. Mean Warner-Bratzler shear values of early-deboned (45 min, 52 min postmortem, respectively) broiler breast treated 25 min after deboning and respective control companion breasts or after storage (24 h), respectively. Means within a treatment pair with unlike letters are different ($P < 0.05$).

Lyon and Lyon (1997) found a wide range in WBS values in early deboned breasts. The authors reported that breasts decreased in WBS as the deboning time increased. The WBS standard deviation decreased as time before deboning increased (Lyon & Lyon, 1997). The standard deviations for the left and right breasts deboned at 2 h postmortem were 3.09 and 3.12 kg, respectively (Lyon & Lyon, 1997). However, the authors did not find a difference in the side of the carcass with the breast (left or right) in shear values based on postmortem deboning time. Meek et al. (2000) reported a standard deviation of 2.1 kg for the paired differences between early deboned and high pressure HSW-treated breasts. In this study, the HSW treatment appeared to decrease the WBS variability as the standard deviation was 0.90 for the 24 h postmortem, stored and treated (standard deviation, 1.90 control) breasts and 0.78 for the breasts treated 25 min after deboning (standard deviation. 1.40, control).

3.2. Instrumental color

There were no differences ($P > 0.05$) in raw color between HSW treated samples and control companion breasts (Tables 1 and 2, Experiments 1 and 2, respectively) regardless of treatment time. Meek et al. (2000) found a difference in the L^* values of the treated breasts on the skin side. The differences in Meek's study and the current were most likely due to the differences in packaging. The breasts in this study were packaged in a water-filled tube. The breasts in their study were packaged and treated in water-impermeable vacuum bags in the absence of water.

There were no differences in cooked color between the HSW breasts treated 25 min after deboning and the control breasts (Experiment 1). In the cooked samples in Experiment 2 (Table 2), the CIE b^* values of the skin side of the HSW breasts stored 24 h before treatment were lower ($P < 0.05$; less yellow) than the control breasts. In contrast, Meek et al. (2000) did not report differences in the CIE b^* values.

3.3. Cooking loss

There were no differences ($P > 0.05$) in cooking loss between treatments (Table 3). Cooking loss was higher than the values reported by Meek et al. (2000) by an average of 5%. Meek et al. (2000) packaged chicken breasts in moisture impermeable vacuum bags for HSW treatment. Broiler breasts in this study were packaged in water to mimic possible future applications of the HSW technology in commercial applications. It is possible

Table 1
Color (CIE $L^*a^*b^*$ values) for early deboned (52 min postmortem) broiler breasts treated 25 min after deboning with hydrodynamic shockwave treatment and the control breasts (Experiment 1)[a]

	n	Raw color			Cooked color		
Treatment and location		L^*	a^*	b^*	L^*	a^*	b^*
Skin side							
Control	12	56.57 (3.22)	3.62 (2.31)	4.72 1.94)	79.30 (2.42)	4.01 (0.85)	12.93 (0.96)
Hydrodynamic shockwave	12	55.93 (4.71)	4.35 (2.03)	4.89 (2.91)	79.18 (2.12)	4.27 (1.06)	12.17 (0.92)
Bone side							
Control	12	57.42 (3.49)	2.18 (1.26)	1.80 (2.30)	81.51 (2.44)	3.72 (0.87)	12.00 (1.24)
Hydrodynamic shockwave	12	57.38 (4.32)	2.39 (1.60)	1.71 (2.33)	81.36 (2.69)	3.54 (0.99)	11.78 (2.23)

[a] Means within a column and raw or cooked color group are not different ($P > 0.05$). Parenthetical values are standard deviations of the means. Fifteen replications per treatment. Two sample T-tests were used to analyze differences with equal variances.

Table 2
Color (CIE $L^*a^*b^*$ values) for early deboned (45 min postmortem) broiler breasts stored 24 h before hydrodynamic shockwave treatment and the control breasts (Experiment 2)[a]

	n	Raw color			Cooked color		
Treatment and location		L^*	a^*	b^*	L^*	a^*	b^*
Skin side							
Control	30	60.88 (3.06)	1.92 (0.95)	3.99 (2.11)	81.28 (2.72)	2.62 (0.82)	12.14a (1.49)
Hydrodynamic shockwave	30	59.95 (3.08)	1.78 (1.18)	3.50 (1.94)	81.96 (2.74)	2.54 (0.90)	11.69b (1.39)
Bone Side							
Control	30	61.14 (3.30)	1.68 (0.77)	3.79 (1.90)	82.16 (2.96)	2.55 (0.84)	11.62 (0.15)
Hydrodynamic shockwave	30	60.71 (3.09)	1.61 (0.83)	3.56 (1.92)	82.29 (3.16)	2.51 (.076)	11.43 (1.41)

[a] Means within a column and raw or cooked group with unlike letters are different ($P < 0.05$). Parenthetical values are standard deviations of the means. Fifteen replications per treatment. Two sample T-tests were used to analyze differences with equal variances.

Table 3
Cooking loss for hydrodynamic shockwave treated and control companion broiler breasts that were early deboned and sous vide cooked to 78°C internal temperature[a]

Treatment	n	Cooking loss %
Experiment 1 — early deboned (52 min postmortem) breasts hydrodynamic shockwave treated 25 min after deboning		
Control	12	24.0 (0.02)
Hydrodynamic shockwave	12	25.1 (0.02)
Experiment 2 — early deboned (45 min postmortem) breasts hydrodynamic shockwave treated after 24 h of storage at 4°C		
Control	30	27.1 (0.02)
Hydrodynamic shockwave	30	26.8 (0.03)

[a] Means within a column and experiment are not different ($P > 0.05$). Parenthetical values are standard deviations of the means. Fifteen replications per treatment. Two sample T-tests were used to analyze differences with equal variances.

that the breasts in this study initially absorbed water to a point that cooking loss was increased. In comparison, Lyon and Lyon (1993) reported a cooking loss very similar to values found here for the breasts stored 24 h. Lyon and Lyon deboned chicken breasts at 24 h and water cooked the breasts in a manner very similar to the cooking procedure used in this study. Cooking loss for chicken breasts deboned at 2 h and water cooked in Lyon and Lyon (1993) were approximately 5% above the breasts that were deboned at 45 min postmortem in this study.

4. Conclusions

The HSW process can overcome the problem of tenderness associated with early deboning if the breasts are processed after storage (24 h). This provides processors with the option to debone earlier. However, early deboned breasts HSW treated immediately after deboning may require higher pressure shockwaves or delayed treatment with HSW to produce breasts with acceptable tenderness.

Acknowledgements

The authors would like to acknowledge Hydrodyne Incorporated for use of their facility, personnel, and funding for this project.

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